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THE EFFECTS OF DIP SOLDERING UPON VARIOUS BOARD MATERIALS AND SOLDER RESIST USED IN PRINTED CIRCUITS

by

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ABSTRACT

This report describes the procedures in conducting eleven dip soldering tests to determine the effects that dip soldering at various temperatures and times has upon various printed circuit board materials, and solder resist material. It discusses the results and conclusions of these soldering tests.

INTRODUCTION

The first type of printed circuit that came into prominent usage consisted of a ceramic base material. Although this type of material (usually steatite) could withstand high temperature, it had its limitations in that it was restricted to small size circuits due mainly to its inherent physical characteristics. As electronic circuits became more complex and additional stages were required, particularly in the rapidly advancing computer field, it became increasingly evident that in order for printed circuits to survive and become a reality that other materials for increasing the size of the circuit must be used or developed. One of the first materials widely used in the larger printed circuits consisted of a paper base with a phenolic resin impregnated into it. This paper phenolic material had a thin copper sheet adhered to one of its sides and was extensively used in the commercial production of radio and television sets, but one of its shortcomings was its inability to withstand elevated temperatures which military circuits required. Therefore the military advanced to a board material with a higher heat resistance rating which had a glass cloth base and an epoxy type resin impregnated into it. This type of board has been used extensively in military applications, not solely because it has a relatively good heat resistance characteristic but it also possesses great mechanical and impact strength along with other relatively high ratings for electrical characteristics such as insulation resistance, dielectric strength, etc. Various other board materials have been developed, but one type appears to have a superior heat resistance characteristic than the others. This board has a glass cloth base and is impregnated with silicone and therefore has a very high relative heat resistance rating, but its mechanical properties are slightly inferior to the glass epoxy board.

By a rather ironic twist of fate it now appears, with the current trend toward microminiaturization, that the emphasis is again being placed upon smaller circuits. Although the field of microelectronics is rapidly replacing many larger circuits it will probably be sometime in the distant future, if at all, before most standard sized printed circuit boards will become obsolete. Even if that condition becomes a reality, the information obtained from the development of printed circuits will probably be invaluable. Therefore, it seems almost mandatory to explore and maintain all possible and practical applications in the field of printed circuitry.

The subject of solder resist entertains a rather unique position in the printed circuit field. In its initial conception, the use of a solder resist was based primarily upon a desire to save solder. Today rapid advancements in resist technology have resulted in far greater usage than previously envisioned. Its application as an aid in better soldering has become well known. In this use, the resist not only protects the conductive pattern and the board itself from excessive heat in dip soldering but also eliminates

solder bridging between conductor patterns. Other uses include circuit contamination protection, high circuit surface insulation resistance and circuit pattern protection during field repair. The use of a solder resist should be incorporated during the design stages of the printed circuit for maximum protection and utilization.

PROCEDURE

The project was accomplished in two phases. The first part consisted of seven tests in which seven various types of circuit board materials were evaluated. The procedure for each test was conducted in an identical manner. The printed circuit board itself was 3" x 5" in size with a 2 ounce, 1/16" thick single sided copper foil.

The boards were all cut to size for the initial operation. The circuit pattern was applied to each board by means of the silk screen method (see Figure 1). The black etchant resist ink was applied to the boards through the screen by means of a squeegee. When the resist was sufficiently dry, the boards were then placed into a spray-etching machine which had Ferric Chloride as its etching solution. Etching was accomplished in approximately two seconds. The resist ink was then removed in a Trichlorethylene solution thus leaving the desired circuit pattern. At this stage, the boards were hand scrubbed using a scrub cleaner and thoroughly rinsed in running tap water, and then air dried. A resin type flux was then applied to each board by brush and allowed to dry (See Figure 2). The dip soldering of the boards was accomplished by two men; one operated the electric timer and gave the signal when to start and stop soldering, while the other man using a holder with the board fastened to it, dip soldered upon signal (see Figure 3). The solder pot was set to the desired temperature and boards from each group were dip soldered for the various time durations (1, 5, 10, 15, and 20 seconds). The solder pot was then set to the next desired temperature and the above procedure was followed until all of the boards were soldered. The soldering temperatures ranged from 450°F to 625°F. The solder composition used was 60% tin and 40% lead. The final procedure at this phase of the program was to evaluate and determine visually whether or not the boards had blistered.

The second phase of the project consisted of four tests which determined the thermal sensitivity of solder resist material. The tests entailed the selection of the optimum methods and materials utilized in applying a solder resist upon a printed circuit board. The physical dimensions of the board, circuit pattern, processes and materials employed in placing the pattern on the board were identical to those described in phase one of the project. The circuit board material used was glass epoxy, single clad, military type GEE.

Once the circuit pattern was established, each board was hand scrubbed

using a scrub cleaner and rinsed in running tap water. (See Chart 3 and Chart 4). It is important that the copper circuit side of the board be free from fingerprints, oils, or other agents that may reduce the adhesion and resistance of the selective solder resist. To insure complete removal of all the surface oxides and insoluable complexes each board was also etched in a copper cleaning solution for two minutes at a temperature of 150°F and rinsed in running tap water. The boards were now ready for selective test evaluation.

The printed circuit boards used in Solder Resist Test 8 and Test 9 utilized a water based flux. A formulated water dip lacquer supposedly acting as a solder assist was used in Test 8.

All the boards in Test 8 were immersed for two minutes in the water dip lacquer, dried for one minute at 200°F and allowed to cool to room temperature.

From this stage on, the methods and materials employed in Test 8 and Test 9 were identical. The solder resist was silk screened onto the printed circuit pattern where solder take was not desired. The connecting tabs and pads were left uncoated to permit soldering.

The solder resist was cured for thirty-five (35) minutes at 270°F. Following the curing cycle, each board had flux applied by brush and allowed to dry.

The techniques and equipment employed in dip soldering the boards were similar to those used in phase one of the project. The solder bath temperature was electrically controlled and maintained within $\pm$ 2°F of each desired temperature. Each group of boards encompassing a specified temperature setting were dip soldered for the various time durations (1, 2.5, 5, 10 and 12.5 seconds) and the results were duly recorded. The soldering temperature ranged from 450°F to 600°F.

Following the soldering operation, the solder resist was removed and the boards were rinsed in running tap water and then forced air dried.

Solder Resist Test 10 and Test 11 were performed in an identical manner to Test 8 and Test 9 with the exception that a resin type flux was used in place of the water based flux. (See Chart 5 and Chart 6).

The final step in the procedure was to evaluate the thermal sensitivity of the solder resist.

The objective of the work reported herein was to determine the effects dip soldering temperatures and times have upon the heat resistance characteristics of various printed circuit board materials based upon the blistering

of the board material itself and the solder temperature effects upon solder resist material.

RESULTS AND DISCUSSION

The results of the first seven tests provides a good working yardstick for the determination and selection of printed circuit boards which will afford good heat resistance characteristics. Although this information is rendered by the board manufacturers, the results obtained from these experiments did not always conform to their data. The boards in these tests were evaluated strictly upon visual inspection and determined to have no blisters or having blisters without regard to the degree of blistering. This method of evaluation was considered optimum under the assumption that if a board were blistered to any extent it would be unaccepted in a circuit.

The boards in Test No. 1 did not exhibit any signs of blistering until the temperature of 600° had been reached. This was somewhat surprising considering that the board material was paper phenolic and had the lowest heat resistance rating of the group (See Chart 1). Although it must be stated that when the boards in this test finally blistered they deteriorated rather badly (See Figure 4). The board shown had more blisters than any other board in the entire seven tests. Six boards in this test blistered.

The results of Test No. 2 was also rather unpredictable in that it too had a relatively low heat resistance and did not blister until 625°F. This board material (paper epoxy) did not deteriorate as badly as the paper phenolic, and actually performed better than any other material in the tests with the exception of the glass silicon board. Only one board in this test blistered and that being the last one which had the highest temperature (625°F) and the longest soldering time (20 seconds).

The results of Test No. 3 also indicated that regardless of the heat resistance rating, which was considered relatively low for this type of board material, these boards withstood relatively high soldering temperatures for long time durations. The one significant feature about these nylon phenolic boards was that when they eventually broke down from the soldering parameters they warped very badly (See Figure 5). Three boards blistered in this test. The largest blister in the entire tests was found in this group (See Figure 6). It is quite apparent from the results shown in the first three tests that these boards performed unusually well considering their innate heat resistance characteristics.

The board with the lowest blister temperature (550°F) of the entire program was obtained from Test No. 4 (See Figure 7). The board material in this test was glass melamine and although it blistered at the lowest

temperature of the tests it did not display the severe warpage or extreme blistering as some of the boards in the previous tests had shown. A total of eight boards had blistered in this test and a pattern was set in that each soldering temperature after and including 550°F blistered at 15 and 20 seconds.

The most commonly used board material for military applications is glass epoxy and was used in Test No. 5. This material has a relatively high heat resistance rating, but did not perform as well as the boards in the first three tests, although none of these boards blistered severely. There were five boards that blistered in this test.

A different type of glass epoxy board was used in Test No. 6 and did disclose a better heat resistance performance than the material used in the previous test. The heat resistance rating of this board was the second highest in the entire tests, and only two boards blistered in this test.

The only board material in the entire seven tests which did not blister was the glass silicone board used in Test No. 7 (See Figure 9). These results were somewhat to be expected as this material had the highest relative heat resistance of the group. From a purely technical basis this material would probably be the optimum choice for a heat resistance circuit board, but its prohibitive cost at the present time would leave something to be desired in that field. Alth ugh the objective of these experiments was not to determine the financial aspects of printed circuit board materials.

The results of the last four tests indicate a working technology has been obtained in applying a solder resist material upon a printed circuit board that will withstand common dip soldering temperatures. As in the first phase of the project, the information noted is available from chemical manufacturers catering to the printed circuit industry but the results obtained from these tests did not constantly conform to their data. All the boards in these tests were visually inspected for resist breakdown and qualitatively classified as good, fair or poor. Boards listed as good showed no resist breakdown (See Figure 10). Boards listed as fair showed a slight resist breakdown but inconsequential as far as it would effect the operation of the circuit. Finally, those noted as poor showed resist breakdown of such a nature as to impair specified circuit operation (See Figure 11).

As indicated in the legend, a water based flux and water dip lacquer acting as a preservative were used in Test No. 8. Resist breakdown in this test was first noted at 500°F after 12.5 seconds in the dip solder bath. Above 500°F the ability of the resist to withstand thermal shock decreases rapidly and a definite correlation can be seen between temperature and circuit board immersion in the solder pot. Of the forty-two boards tested, seven (7) were listed as fair and seven (7) were judged as poor.

Though no preservative was used in Test No. 9 the solder resist exhibited a greater resistance to thermal shock than was shown in the prior test. Partial resist breakdown was first encountered at 525°F after 12.5 seconds immersion in

the solder pot. As stated previously, a definite correlation between board condition and temperature-time immersion is evident, however, this relationship started higher in the temperature scale and solder resist breakdown was not as drastic. Here three (3) fair and (4) poor boards were noted.

In Test No. 10, a resin type flux was used in conjunction with the water dip lacquer. Partial solder resist breakdown was recorded in this test after ten (10) seconds at a temperature of 550°F. The results were summarized here as five (5) fair and four (4) poor.

Test No. 11 was conducted using a resin flux without preservative. The resist here exhibited the highest resistance to thermal shock. Partial breakdown was noted at 550°F after 12.5 seconds immersion in the solder pot. The quantitative count here were four (4) fair boards and three (3) poor boards.

The results of the last four tests indicate a trend. A water based flux in conjunction with a water dip lacquer lowered the resistance of the solder resist material. When the preservative was eliminated, the solder resist exhibited a much greater ability to withstand thermal shock.

A similar but not quite as drastic relationship was noted between Test No. 10 and Test No. 11.

CONCLUSIONS

Only one type of printed circuit board material (glass silicone) of the seven various types of materials used in the blistering tests did not blister.

The other six board materials exhibited to varying degrees the deleterious effects that dip soldering temperatures and times had upon them. The results were not always in accordance with the innate heat resistance characteristics designated to each material.

Although the paper phenolic and glass melamine board materials did not blister at temperatures as low as some other board materials in these experiments, they did display the most blistering effects and warpage of all the materials examined.

Solder resists can successfully be applied and withstand the thermal shock experienced by a printed circuit board during standard dip soldering operations.

The water based flux and water dip lacquer were not compatible when used in conjunction with the solder resist. The deleterious effect was evidenced by a reduction in the ability of the solder resist to withstand thermal shock.

With the resin flux, no discernable advantage or disadvantage in solder resist heat resistance was noted by the use or absence of the water dip lacquer.

Figure 1. Applying Circuit Pattern by Silk Screen Method.

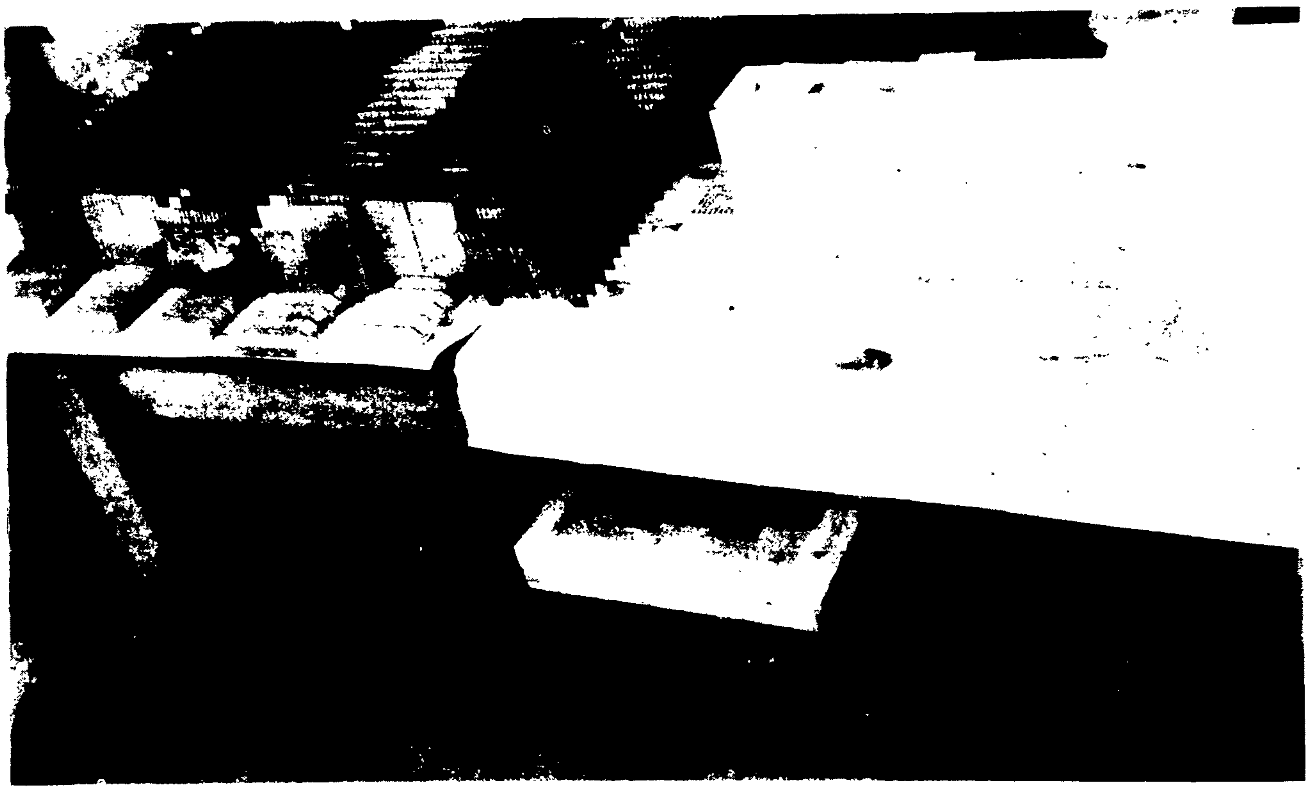

Figure 2. Entire Group of Boards in the Blister Tests with Flux Applied.

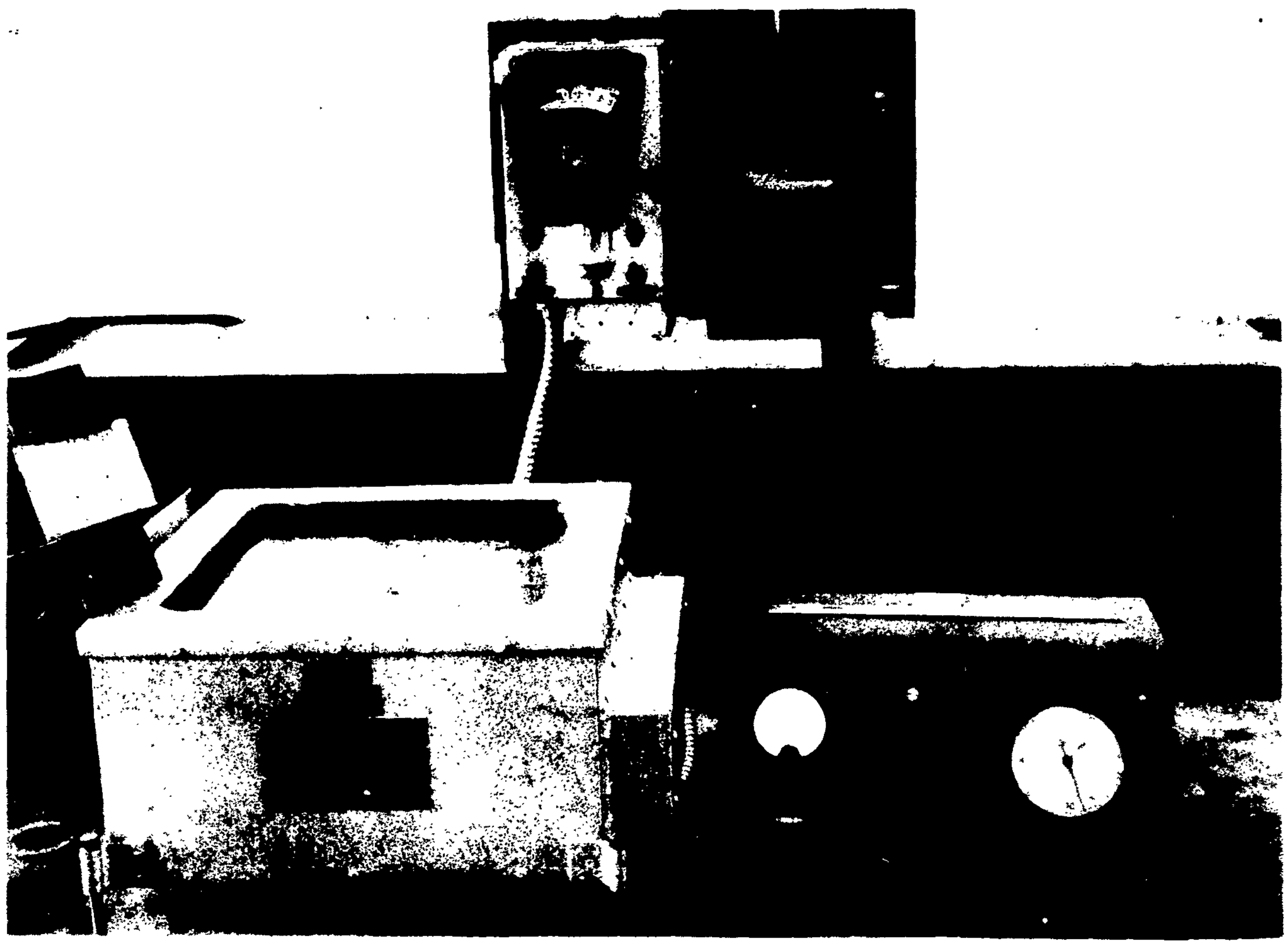

Figure 3. The Dip Soldering Test Arrangement.

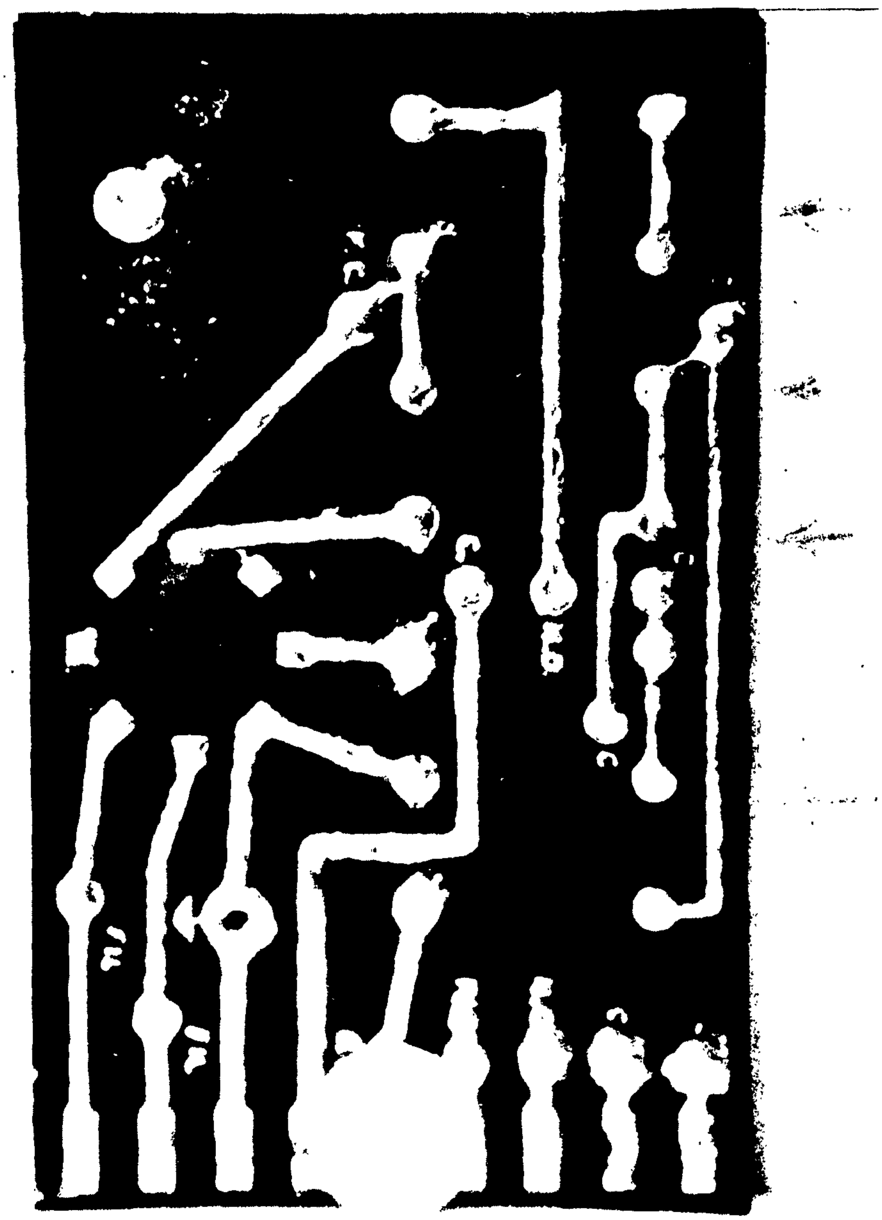

Figure 4. Board No. 40 from Blister Test No. 1 after Soldering Arrows Point to Blisters.

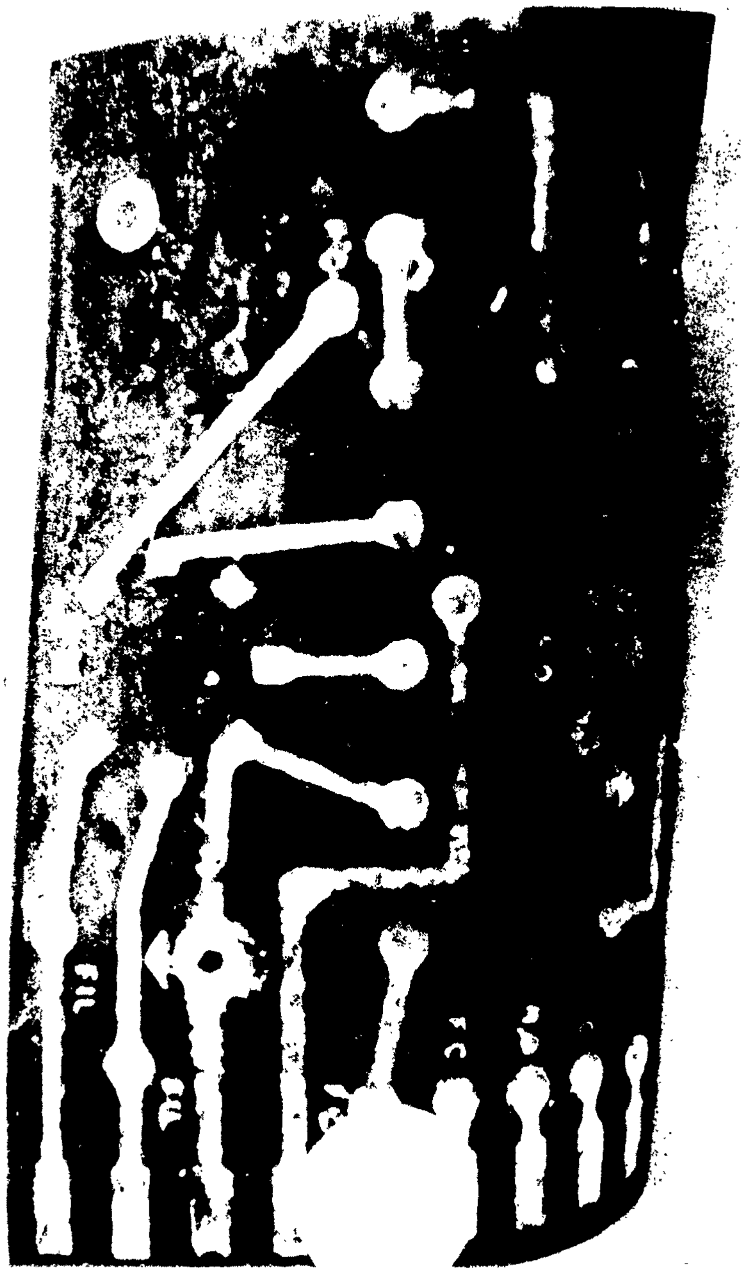

Figure 5. Board No. 40 from Blister Test No. 3 After **Soldering.** Note tremendous warpage.

Figure 6. The Reverse Side of Board No. 40 from Blister Test No. 3. Largest Blister in Entire Tests.

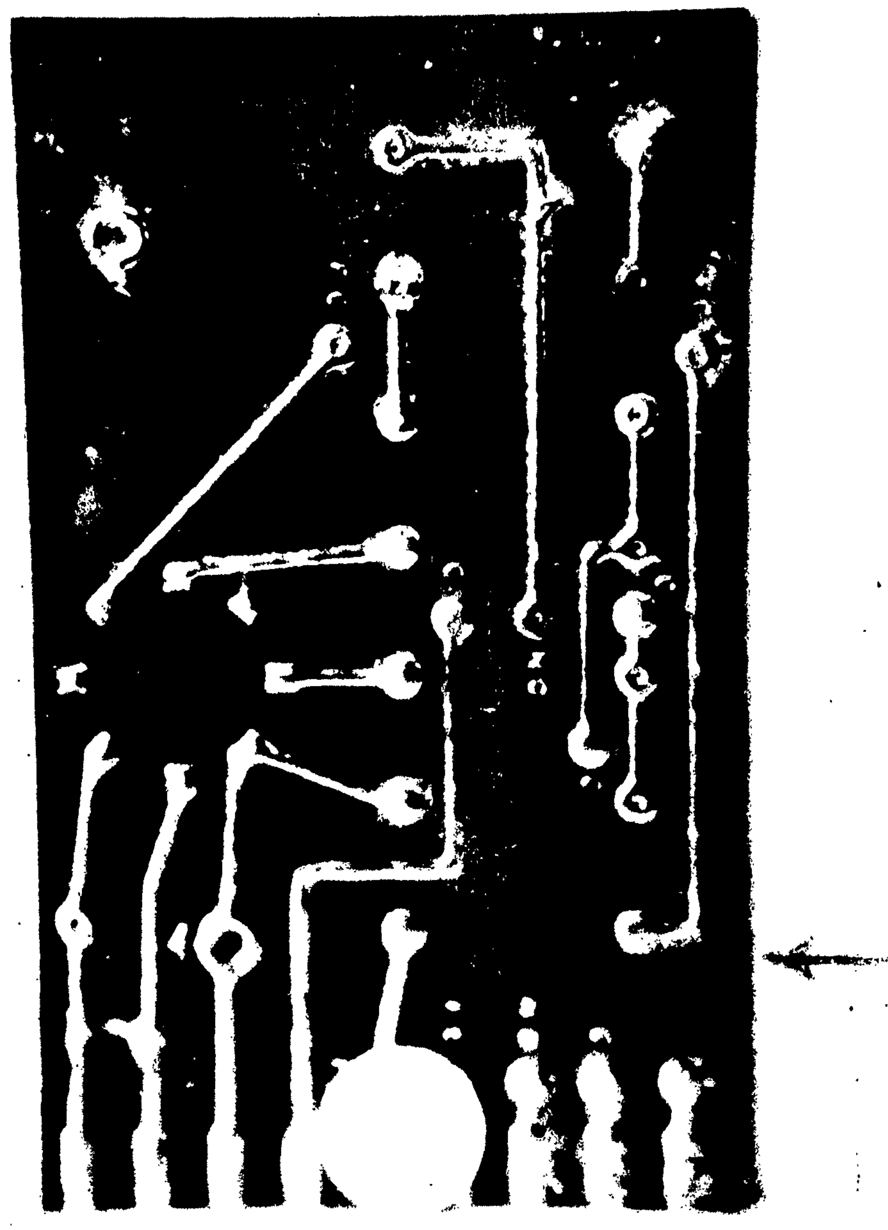

Figure 7. Board No. 24 from Blister Test No. 4 After Soldering. Lowest Blister Temperature of Tests (550F).

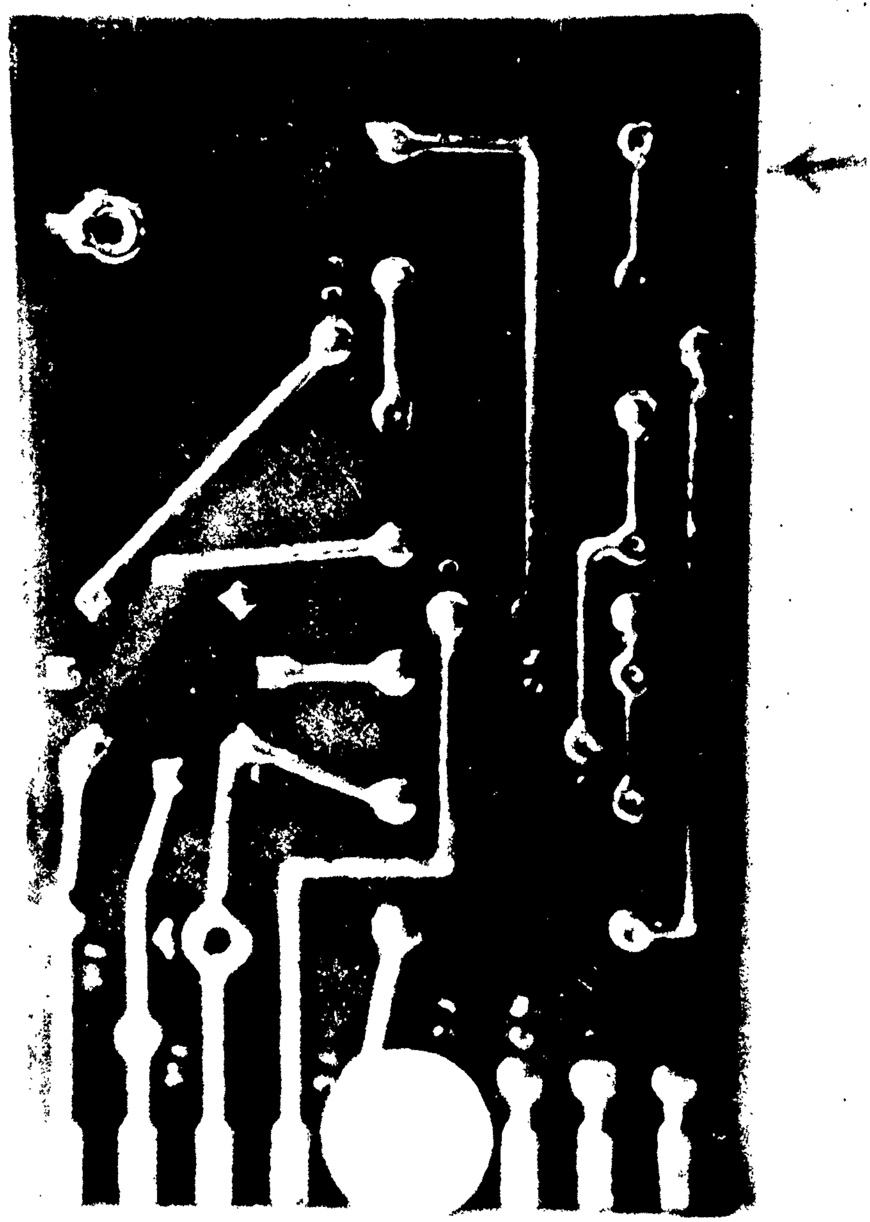

Figure 8. Board No. 30 from Blister Test No. 5 After Soldering. Most Commonly Used Board for Military Applications.

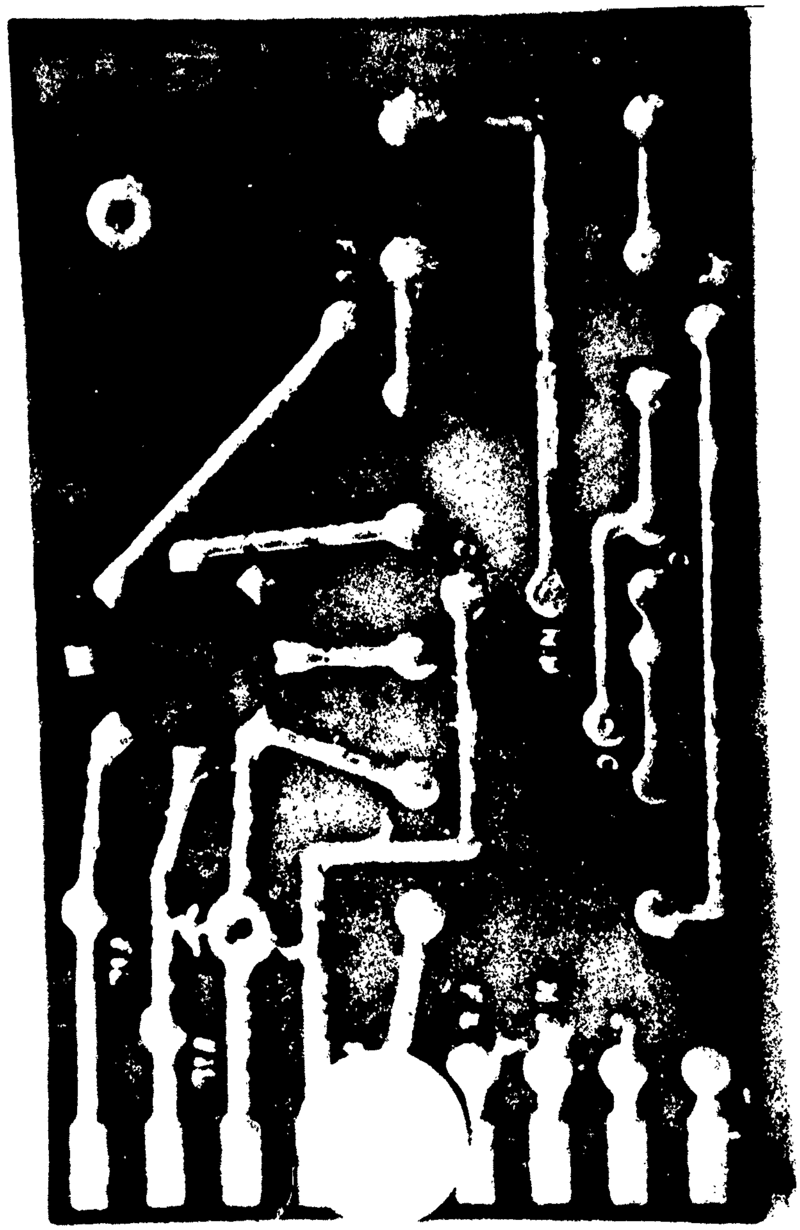

Figure 9. Board No. 40 from Blister Test No. 7 After Soldering. Only Board Material that did not blister.

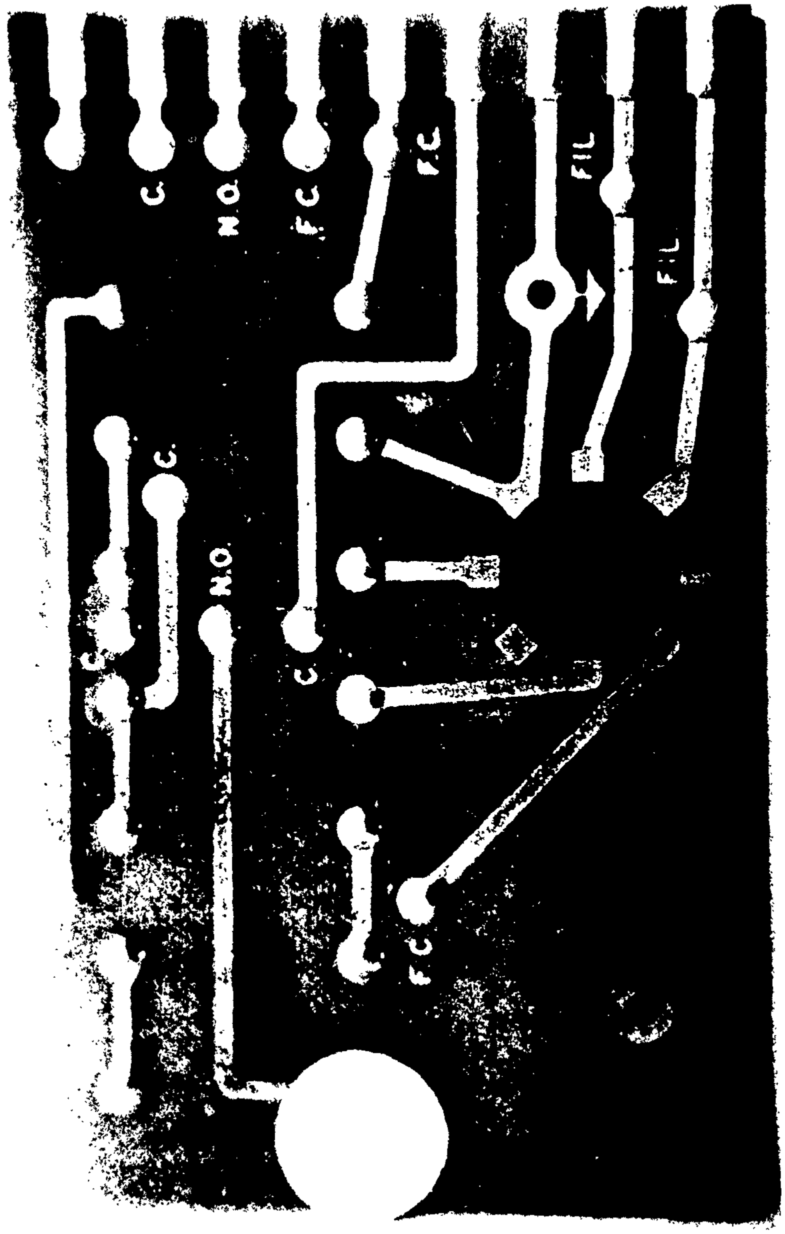

Figure 10. Board No. 17 from Solder **Resist Test No.** 9 After Soldering. The Condition of **This Board** was Evaluated as Good.

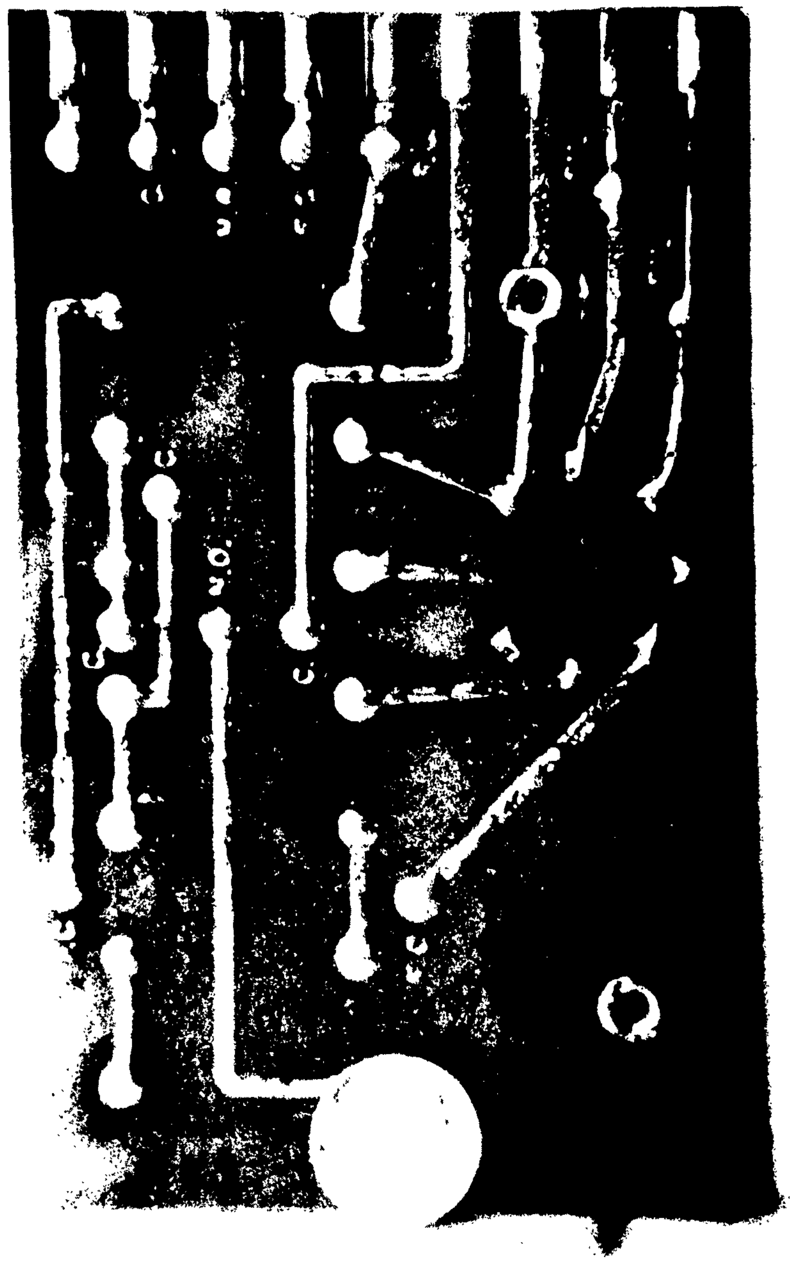

Figure 11. Board No. 41 from Solder Resist Test No. 9 After Soldering. The Condition of this Board was Evaluated as Poor.

CHART ONE

PRINTED CIRCUIT BOARD MATERIAL DATA

BOARD BASE	MAT'L RESIN	MILITARY TYPE	NEMA* GRADE	RELATIVE HEAT RESISTANCE**	PRIMARY APPLICATION
Paper	Phenolic	PBE-P	XXXP	2	Radio & TV boards
Paper	Epoxy	PEE	FR3	3	Terminal Boards
Nylon Cloth	Phenolic	NPG	N-1	3	Postformed PC
Glass Cloth	Melamine	GMG	G-5	5	Switch bases
Glass Cloth	Epoxy	GEE	G-10	6	Computers & missiles
Glass Cloth	Epoxy	GEB	G-11	9	Rocket circuitry
Glass Cloth	Silicone	GSG	G-7	10	Radar, missiles, motors, generators, etc.

* NEMA - National Electrical Manufacturers Association

** Ratings improve with quality from 1 to 10.

CHART TWO

LOWEST BLISTER TEMPERATURE AND TIME FOR EACH BLISTER TEST

TEST NO.	BOARD MATERIAL	TEMP (OF)	TIME (SEC)
1	Paper Phenolic	600	10
2	Paper Epoxy	625	20
3	Nylon Phenolic	600	15
4	Glass Melamine	550	15
5	Glass Epoxy	575	20
6	Glass Epoxy	625	15
7	Glass Silicone	Did not blister	

CHART THREE

WATER BASED FLUX WITH PRESERVATIVE PROCESS

1. Scrub board with suitable scrub cleaner.
2. Water Rinse.
3. Copper cleaning solution immersion for two (2) minutes at 150°F.
4. Water Rinse.
5. Water dip lacquer (preservative) immersion for two (2) minutes.
6. Bake at 200°F for one (1) minute.
7. Cool to room temperature.
8. Silk screen solder resist onto circuit pattern.
9. Cure solder resist for thirty-five (35) minutes at 270°F.
10. Cool to room temperature.
11. Flux board.
12. Air dry.
13. Solder.
14. Apply solder resist remover.
15. Water rinse.
16. Forced air dry.

CHART FOUR

WATER BASED FLUX WITHOUT PRESERVATIVE PROCESS

1. Scrub board with suitable scrub cleaner.
2. Water rinse.
3. Copper cleaning solution immersion for two (2) minutes at 150°F.
4. Water rinse.
5. Silk screen solder resist onto circuit pattern.
6. Cure solder resist for thirty-five (35) minutes at 270°F.
7. Cool to room temperature.
8. Flux board.
9. Air dry.
10. Solder.
11. Apply solder resist remover.
12. Water rinse.
13. Forced air dry.

CHART FIVE

RESIN FLUX WITH PRESERVATIVE PROCESS

1. Scrub board with suitable scrub cleaner.
2. Water rinse.
3. Copper cleaning solution immersion for two (2) minutes at 150°F.
4. Water rinse.
5. Water dip lacquer (preservative) immersion for two (2) minutes.
6. Bake at 200°F for one (1) minute.
7. Cool to room temperature.
8. Silk screen solder resist onto circuit pattern.
9. Cure solder resist for thirty-five (35) minutes at 270°F.
10. Cool to room temperature.
11. Flux board.
12. Air dry.
13. Solder.
14. Apply solder resist remover.
15. Water rinse.
16. Forced air dry.

CHART SIX

RESIN FLUX WITHOUT PRESERVATIVE

1. Scrub board with suitable scrub cleaner.
2. Water rinse.
3. Copper cleaning solution immersion for two (2) minutes at 150°F.
4. Water rinse.
5. Silk screen solder resist onto circuit pattern.
6. Cure solder resist for thirty-five (35) minutes at 270°F.
7. Cool to room temperature.
8. Flux board.
9. Air dry.
10. Solder.
11. Apply solder resist remover.
12. Water rinse.
13. Forced air dry.

TABLE I

BLISTER TEST NO. 1

BOARD MATERIAL: PAPER PHENOLIC
MILITARY TYPE: PBE-P
NOTE: N.B. = No Blisters

BOARD NO.	TEMP (F)	TIME (SEC)	BOARD CONDITION	BOARD NO.	TEMP (F)	TIME (SEC)	BOARD CONDITION
1	450	1	N.B.	21	550	1	N.B.
2	450	5	N.B.	22	550	5	N.B.
3	450	10	N.B.	23	550	10	N.B.
4	450	15	N.B.	24	550	15	N.B.
5	450	20	N.B.	25	550	20	N.B.
6	475	1	N.B.	26	575	1	N.B.
7	475	5	N.B.	27	575	5	N.B.
8	475	10	N.B.	28	575	10	N.B.
9	475	15	N.B.	29	575	15	N.B.
10	475	20	N.B.	30	575	20	N.B.
11	500	1	N.B.	31	600	1	N.B.
12	500	5	N.B.	32	600	5	N.B.
13	500	10	N.B.	33	600	10	Blistered
14	500	15	N.B.	34	600	15	Blistered
15	500	20	N.B.	35	600	20	Blistered
16	525	1	N.B.	36	625	1	N.B.
17	525	5	N.B.	37	625	5	N.B.
18	525	10	N.B.	38	625	10	Blistered
19	525	15	N.B.	39	625	15	Blistered
20	525	20	N.B.	40	625	20	Blistered

TABLE II

BLISTER TEST NO. 2

BOARD MATERIAL: PAPER EPOXY
MILITARY TYPE: PEE
NOTE: N.B. = No Blisters

BOARD NO.	TEMP (F)	TIME (SEC)	BOARD CONDITION	BOARD NO.	TEMP (F)	TIME (SEC)	BOARD CONDITION
1	450	1	N.B.	21	550	1	N.B.
2	450	5	N.B.	22	550	5	N.B.
3	450	10	N.B.	23	550	10	N.B.
4	450	15	N.B.	24	550	15	N.B.
5	450	20	N.B.	25	550	20	N.B.
6	475	1	N.B.	26	575	1	N.B.
7	475	5	N.B.	27	575	5	N.B.
8	475	10	N.B.	28	575	10	N.B.
9	475	15	N.B.	29	575	15	N.B.
10	475	20	N.B.	30	575	20	N.B.
11	500	1	N.B.	31	600	1	N.B.
12	500	5	N.B.	32	600	5	N.B.
13	500	10	N.B.	33	600	10	N.B.
14	500	15	N.B.	34	600	15	N.B.
15	500	20	N.B.	35	600	20	N.B.
16	525	1	N.B.	36	625	1	N.B.
17	525	5	N.B.	37	625	5	N.B.
18	525	10	N.B.	38	625	10	N.B.
19	525	15	N.B.	39	625	15	N.B.
20	525	20	N.B.	40	625	20	Blistered

TABLE III

BLISTER TEST NO. 3

BOARD MATERIAL: NYLON PHENOLIC
MILITARY TYPE: NPG
NOTE: N.B. = No Blisters

BOARD NO.	TEMP (F)	TIME (SEC)	BOARD CONDITION	BOARD NO.	TEMP (F)	TIME (SEC)	BOARD CONDITION
1	450	1	N.B.	21	550	1	N.B.
2	450	5	N.B.	22	550	5	N.B.
3	450	10	N.B.	23	550	10	N.B.
4	450	15	N.B.	24	550	15	N.B.
5	450	20	N.B.	25	550	20	N.B.
6	475	1	N.B.	26	575	1	N.B.
7	475	5	N.B.	27	575	5	N.B.
8	475	10	N.B.	28	575	10	N.B.
9	475	15	N.B.	29	575	15	N.B.
10	475	20	N.B.	30	575	20	N.B.
11	500	1	N.B.	31	600	1	N.B.
12	500	5	N.B.	32	600	5	N.B.
13	500	10	N.B.	33	600	10	N.B.
14	500	15	N.B.	34	600	15	Blistered
15	500	20	N.B.	35	600	20	Blistered
16	525	1	N.B.	36	625	1	N.B.
17	525	5	N.B.	37	625	5	N.B.
18	525	10	N.B.	38	625	10	N.B.
19	525	15	N.B.	39	625	15	N.B.
20	525	20	N.B.	40	625	20	Blistered

TABLE III

BLISTER TEST NO. 3

BOARD MATERIAL: NYLON PHENOLIC
MILITARY TYPE: NPG
NOTE: N.B. = No Blisters

BOARD NO.	TEMP (F)	TIME (SEC)	BOARD CONDITION	BOARD NO.	TEMP (F)	TIME (SEC)	BOARD CONDITION
1	450	1	N.B.	21	550	1	N.B.
2	450	5	N.B.	22	550	5	N.B.
3	450	10	N.B.	23	550	10	N.B.
4	450	15	N.B.	24	550	15	N.B.
5	450	20	N.B.	25	550	20	N.B.
6	475	1	N.B.	26	575	1	N.B.
7	475	5	N.B.	27	575	5	N.B.
8	475	10	N.B.	28	575	10	N.B.
9	475	15	N.B.	29	575	15	N.B.
10	475	20	N.B.	30	575	20	N.B.
11	500	1	N.B.	31	600	1	N.B.
12	500	5	N.B.	32	600	5	N.B.
13	500	10	N.B.	33	600	10	N.B.
14	500	15	N.B.	34	600	15	**Blistered**
15	500	20	N.B.	35	600	20	**Blistered**
16	525	1	N.B.	36	625	1	N.B.
17	525	5	N.B.	37	625	5	N.B.
18	525	10	N.B.	38	625	10	N.B.
19	525	15	N.B.	39	625	15	N.B.
20	525	20	N.B.	40	625	20	N.B.

TABLE IV

BLISTER TEST NO. 4

BOARD MATERIAL: GLASS MELAMINE
MILITARY TYPE: GMG
NOTE: N.B. = No Blisters

BOARD NO.	TEMP (F)	TIME (SEC)	BOARD CONDITION	BOARD NO.	TEMP (F)	TIME (SEC)	BOARD CONDITION
1	450	1	N.B.	21	550	1	N.B.
2	450	5	N.B.	22	550	5	N.B.
3	450	10	N.B.	23	550	10	N.B.
4	450	15	N.B.	24	550	15	Blistered
5	450	20	N.B.	25	550	20	Blistered
6	475	1	N.B.	26	575	1	N.B.
7	475	5	N.B.	27	575	5	N.B.
8	475	10	N.B.	28	575	10	N.B.
9	475	15	N.B.	29	575	15	Blistered
10	475	20	N.B.	30	575	20	Blistered
11	500	1	N.B.	31	600	1	N.B.
12	500	5	N.B.	32	600	5	N.B.
13	500	10	N.B.	33	600	10	N.B.
14	500	15	N.B.	34	600	15	Blistered
15	500	20	N.B.	35	600	20	Blistered
16	525	1	N.B.	36	625	1	N.B.
17	525	5	N.B.	37	625	5	N.B.
18	525	10	N.B.	38	625	10	N.B.
19	525	15	N.B.	39	625	15	Blistered
20	525	20	N.B.	40	625	20	Blistered

TABLE V

BLISTER TEST NO. 5

BOARD MATERIAL: GLASS EPOXY
MILITARY TYPE: GEE
NOTE: N.B. = No Blister

BOARD NO.	TEMP (F)	TIME (SEC)	BOARD CONDITION	BOARD NO.	TEMP (F)	TIME (SEC)	BOARD CONDITION
1	450	1	N.B.	21	550	1	N.B.
2	450	5	N.B.	22	550	5	N.B.
3	450	10	N.B.	23	550	10	N.B.
4	450	15	N.B.	24	550	15	N.B.
5	450	20	N.B.	25	550	20	N.B.
6	475	1	N.B.	26	575	1	N.B.
7	475	5	N.B.	27	575	5	N.B.
8	475	10	N.B.	28	575	10	N.B.
9	475	15	N.B.	29	575	15	N.B.
10	475	20	N.B.	30	575	20	Blistered
11	500	1	N.B.	31	600	1	N.B.
12	500	5	N.B.	32	600	5	N.B.
13	500	10	N.B.	33	600	10	N.B.
14	500	15	N.B.	34	600	15	Blistered
15	500	20	N.B.	35	600	20	Blistered
16	525	1	N.B.	36	625	1	N.B.
17	525	5	N.B.	37	625	5	N.B.
18	525	10	N.B.	38	625	10	N.B.
19	525	15	N.B.	39	625	15	Blistered
20	525	20	N.B.	40	625	20	Blistered

TABLE VI

BLISTER TEST NO. 6

BOARD MATERIAL: GLASS EPOXY
MILITARY TYPE: GEB
NOTE: N.B. = No Blister

BOARD NO.	TEMP (F)	TIME (SEC)	BOARD CONDITION	BOARD NO.	TEMP (F)	TIME (SEC)	BOARD CONDITION
1	450	1	N.B.	21	550	1	N.B.
2	450	5	N.B.	22	550	5	N.B.
3	450	10	N.B.	23	550	10	N.B.
4	450	15	N.B.	24	550	15	N.B.
5	450	20	N.B.	25	550	20	N.B.
6	475	1	N.B.	26	575	1	N.B.
7	475	5	N.B.	27	575	5	N.B.
8	475	10	N.B.	28	575	10	N.B.
9	475	15	N.B.	29	575	15	N.B.
10	475	20	N.B.	30	575	20	N.B.
11	500	1	N.B.	31	600	1	N.B.
12	500	5	N.B.	32	600	5	N.B.
13	500	10	N.B.	33	600	10	N.B.
14	500	15	N.B.	34	600	15	N.B.
15	500	20	N.B.	35	600	20	N.B.
16	525	1	N.B.	36	625	1	N.B.
17	525	5	N.B.	37	625	5	N.B.
18	525	10	N.B.	38	625	10	N.B.
19	525	15	N.B.	39	625	15	Blistered
20	525	20	N.B.	40	625	20	Blistered

TABLE VII

BLISTER TEST NO. 7

BOARD MATERIAL: GLASS SILICONE
MILITARY TYPE: GSG
NOTE: N.B. = No Blisters

BOARD NO.	TEMP (F)	TIME (SEC)	BOARD CONDITION	BOARD NO.	TEMP (F)	TIME (SEC)	BOARD CONDITION
1	450	1	N.B.	21	550	1	N.B.
2	450	5	N.B.	22	550	5	N.B.
3	450	10	N.B.	23	550	10	N.B.
4	450	15	N.B.	24	550	15	N.B.
5	450	20	N.B.	25	550	20	N.B.
6	475	1	N.B.	26	575	1	N.B.
7	475	5	N.B.	27	575	5	N.B.
8	475	10	N.B.	28	575	10	N.B.
9	475	15	N.B.	29	575	15	N.B.
10	475	20	N.B.	30	575	20	N.B.
11	500	1	N.B.	31	600	1	N.B.
12	500	5	N.B.	32	600	5	N.B.
13	500	10	N.B.	33	600	10	N.B.
14	500	15	N.B.	34	600	15	N.B.
15	500	20	N.B.	35	600	20	N.B.
16	525	1	N.B.	36	625	1	N.B.
17	525	5	N.B.	37	625	5	N.B.
18	525	10	N.B.	38	625	10	N.B.
19	525	15	N.B.	39	625	15	N.B.
20	525	20	N.B.	40	625	20	N.B.

TABLE VIII

SOLDER RESIST TEST NO. 8

FLUX USED: WATER BASED
PRESERVATIVE: WATER DIP LACQUER

BOARD NO.	TEMP (^{o}F)	TIME (SEC)	PATTERN RESIST CONDITION	BOARD NO.	TEMP (^{o}F)	TIME (SEC)	PATTERN RESIST CONDITION
1	450	1.0	Good	22	525	7.5	Good
2	450	2.5	Good	23	525	10.0	Fair
3	450	5.0	Good	24	525	12.5	Fair
4	450	7.5	Good				
5	450	10.0	Good	25	550	1.0	Good
6	450	12.5	Good	26	550	2.5	Good
				27	550	5.0	Good
7	475	1.0	Good	28	550	7.5	Fair
8	475	2.5	Good	29	550	10.0	Fair
9	475	5.0	Good	30	550	12.5	Poor
10	475	7.5	Good				
11	475	10.0	Good	31	575	1.0	Good
12	475	12.5	Good	32	575	2.5	Good
				33	575	5.0	Fair
13	500	1.0	Good	34	575	7.5	Poor
14	500	2.5	Good	35	575	10.0	Poor
15	500	5.0	Good	36	575	12.5	Poor
16	500	7.5	Good				
17	500	10.0	Good	37	600	1.0	Good
18	500	12.5	Fair	38	600	2.5	Good
				39	600	5.0	Fair
19	525	1.0	Good	40	600	7.5	Poor
20	525	2.5	Good	41	600	10.0	Poor
21	525	5.0	Good	42	600	12.5	Poor

TABLE IX

SOLDER RESIST TEST NO. 9

FLUX USED: WATER BASED
PRESERVATIVE: NONE

BOARD NO.	TEMP (°F)	TIME (SEC)	PATTERN RESIST CONDITION	BOARD NO.	TEMP (°F)	TIME (SEC)	PATTERN RESIST CONDITION
1	450	1.0	Good	22	525	7.5	Good
2	450	2.5	Good	23	525	10.0	Good
3	450	5.0	Good	24	525	12.5	Fair
4	450	7.5	Good				
5	450	10.0	Good	25	550	1.0	Good
6	450	12.5	Good	26	550	2.5	Good
				27	550	5.0	Good
7	475	1.0	Good	28	550	7.5	Good
8	475	2.5	Good	29	550	10.0	Good
9	475	5.0	Good	30	550	12.5	Fair
10	475	7.5	Good				
11	475	10.0	Good	31	575	1.0	Good
12	475	12.5	Good	32	575	2.5	Good
				33	575	5.0	Good
13	500	1.0	Good	34	575	7.5	Good
14	500	2.5	Good	35	575	10.0	Fair
15	500	5.0	Good	36	575	12.5	Poor
16	500	7.5	Good				
17	500	10.0	Good	37	600	1.0	Good
18	500	12.5	Good	38	600	2.5	Good
				39	600	5.0	Good
19	525	1.0	Good	40	600	7.5	Poor
20	525	2.5	Good	41	600	10.0	Poor
21	525	5.0	Good	42	600	12.5	Poor

TABLE X

SOLDER RESIST TEST NO. 10

FLUX USED: RESIN
PRESERVATIVE: WATER DIP LACQUER

BOARD NO.	TEMP (°F)	TIME (SEC)	PATTERN RESIST CONDITION	BOARD NO.	TEMP (°F)	TIME (SEC)	PATTERN RESIST CONDITION
1	450	1.0	Good	22	525	7.5	Good
2	450	2.5	Good	23	525	10.0	Good
3	450	5.0	Good	24	525	12.5	Good
4	450	7.5	Good				
5	450	10.0	Good	25	550	1.0	Good
6	450	12.5	Good	26	550	2.5	Good
				27	550	5.0	Good
7	475	1.0	Good	28	550	7.5	Good
8	475	2.5	Good	29	550	10.0	Fair
9	475	5.0	Good	30	550	12.5	Fair
10	475	7.5	Good				
11	475	10.0	Good	31	575	1.0	Good
12	475	12.5	Good	32	575	2.5	Good
				33	575	5.0	Good
13	500	1.0	Good	34	575	7.5	Fair
14	500	2.5	Good	35	575	10.0	Fair
15	500	5.0	Good	36	575	12.5	Poor
16	500	7.5	Good				
17	500	10.0	Good	37	600	1.0	Good
18	500	12.5	Good	38	600	2.5	Good
				39	600	5.0	Fair
19	525	1.0	Good	40	600	7.5	Poor
20	525	2.5	Good	41	600	10.0	Poor
21	525	5.0	Good	42	600	12.5	Poor

TEST XI

SOLDER RESIST TEST NO. 11

FLUX USED: RESIN
PRESERVATIVE: NONE

BOARD NO.	TEMP (°F)	TIME (SEC)	PATTERN RESIST CONDITION	BOARD NO.	TEMP (°F)	TIME (SEC)	PATTERN RESIST CONDITION
1	450	1.0	Good	22	525	7.5	Good
2	450	2.5	Good	23	525	10.0	Good
3	450	5.0	Good	24	525	12.5	Good
4	450	7.5	Good				
5	450	10.0	Good	25	550	1.0	Good
6	450	12.5	Good	26	550	2.5	Good
				27	550	5.0	Good
7	475	1.0	Good	28	550	7.5	Good
8	475	2.5	Good	29	550	10.0	Good
9	475	5.0	Good	30	550	12.5	Fair
10	475	7.5	Good				
11	475	10.0	Good	31	575	1.0	Good
12	475	12.5	Good	32	575	2.5	Good
				33	575	5.0	Good
13	500	1.0	Good	34	575	7.5	Good
14	500	2.5	Good	35	575	10.0	Fair
15	500	5.0	Good	36	575	12.5	Poor
16	500	7.5	Good				
17	500	10.0	Good	37	600	1.0	Good
18	500	12.5	Good	38	600	2.5	Good
				39	600	5.0	Fair
19	525	1.0	Good	40	600	7.5	Fair
20	525	2.5	Good	41	600	10.0	Poor
21	525	5.0	Good	42	600	12.5	Poor

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